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Sensorless Operation of Brushless DC Motor Drive using Back EMF Technique

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Abstract- The Brushless Direct Current (BLDC) motors are one of the motor types that is gaining rapid popularity. Its major appliances include refrigerators, washing machines, vacuum cleaners, freezers, etc. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. This paper proposes a new optimized technique for the Sensorless operation of permanent magnet brushless direct current (BLDC) motor, which is based on back Electro Motive Force (back EMF), Zero Crossing Detection (ZCD). This proposed commutation technique of BLDC motor significantly reduces sensing circuits and cost of motor drive.
Keywords : **Back Electromotive Force (EMF), Brushless DC (BLDC) motor, Sensorless control, Zero Crossing Detection.**

I.INTRODUCTION

In recent years, the Brushless DC Motor is receiving great interest in automotive applications, especially on vehicle fuel pumps due to its high efficiency. In addition to this, BLDC motors do not use brushes for commutation; since because, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors [2]. A few of these are:

- Increased Reliability & Efficiency
- Longer Life
- Elimination of Sparks from Commutator
- Reduced Friction
- Faster Rate of Voltage & Current
- Precision Voltage & Current Applied to Field Coils

In order to obtain an accurate and ripple-free, instantaneous torque of BLDC motor, the rotor position information for stator current commutation must be known, which can be obtained using Hall sensors mounted on a rotor. As a known fact, If any sensors are used to detect rotor position, then sensed information must be transferred to a control unit. Therefore, additional connections to the motor are necessary. This may not be acceptable for some applications. There are some reasons to eliminate the position sensors:

- Inability to make additional connections between position sensors and the control unit
- Cost of the position sensors and wiring
- Need special mechanical arrangements to be mounted
- These sensors are temperature sensitive, and hence limit the operation of the motor
- Can also reduce system stability because of the extra components and wiring

In order to overcome these limitations, we are opting the sensor less control technique for brushless DC motor.

In this paper, the proposed Sensorless technique is based on back-EMF estimation. However, when a motor is at a stand still or very low speed, it is well known that the back-EMF is too small to estimate a precise rotor position. Therefore, a specific start-up process is required. The procedure is to excite two phases of the three-phase windings for a preset time. The permanent magnet rotor will then rotate to align to a specific position. With a known initial rotor position and a given commutation logic, an open-loop control scheme is then applied to accelerate the motor from standstill. Thus the commutation logic is obtained from back emf zero crossing detection [7].

II. CONVENTIONAL SENSOR CONTROL METHOD

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor the stator windings should be energized in a sequence. It is important to know the Rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall-effect sensors embedded into the stator.

Most BLDC motors have three Hall sensors inside the stator on the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors they give a high or low signal indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined. Hall sensors are embedded in the stationary part of the motor. Embedding the Hall sensors into the stator is a complex process because any misalignment in these Hall sensors with respect to the rotor magnets will generate an error in the determination of the rotor position.

Thus the hall position sensors will increase the cost and the size of the motor, and also a special mechanical arrangement needs to be made for sensor mounting. They could reduce the system reliability due to increased number of the components and hardware interfacing. Moreover, they are temperature sensitive, which could limit the motor operation at high temperatures. In some applications, it even may not be possible to mount any position sensor on the motor.

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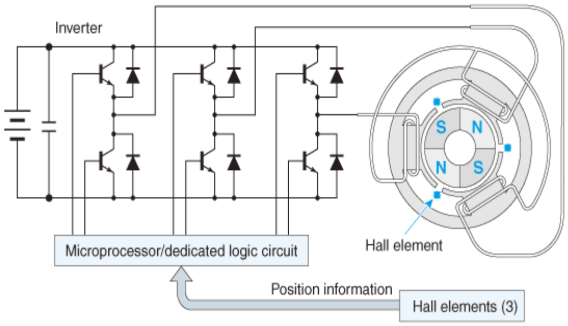

Fig. 1. BLDC with sensor control

Therefore, Sensorless control of BLDC motor based on back emf zero crossing detection has been receiving great interest in recent years.

III. Proposed Back Emf Zero Crossing Detection Method

The zero-crossing approach is one of the simplest methods of back-EMF sensing technique, and is based on detecting the instant at which the back-EMF in the unexcited phase crosses zero [3]. This zero crossing triggers a timer, which may be as simple as an RC time constant, so that the next sequential inverter commutation occurs at the end of this timing interval.

In typical operation of a BLDC motor, the phase current and back-EMF should be aligned to generate constant torque [6], [8]. The current commutation point can be estimated by the zero crossing point (ZCP) of back-EMFs and a 30° phase shift using a six-step commutation scheme through a three-phase inverter for driving the BLDC motor. The conducting interval for each phase is 120 electrical degrees. Therefore, only two phases conduct current at any time, leaving the third phase floating. In order to produce maximum torque, the inverter should be commutated every 60° by detecting zero crossing of back-EMF [1] on the floating coil of the motor, so that current is in phase with the back-EMF.

This technique of delaying 30° (electrical degrees) from zero crossing instant of the back-EMF is not affected much by speed changes. To detect the ZCPs [5], the phase back-EMF should be monitored during the silent phase (when the particular phase current is zero) and the terminal voltages should be low-pass filtered first.

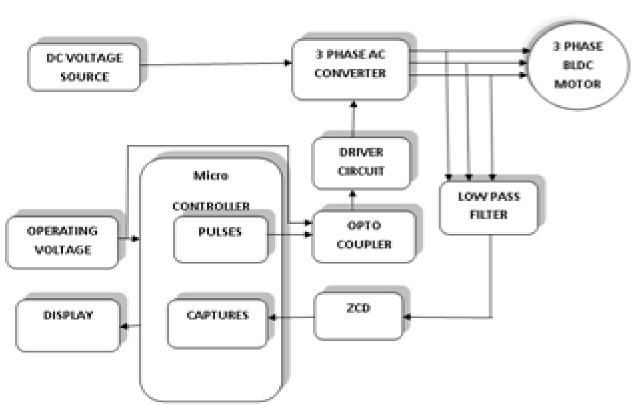

Fig 2. Complete Block Diagram

The advantages of the proposed methods are as follows:

- Increased system reliability
- Reduced hardware cost
- Reduced feedback units
- Decreased system size

A. *Inverter circuit*

The DC voltage is applied to the inverter. The Inverter circuit consists of single legs MOSFET circuit (Half Bridge). MOSFET (IRF840) switch is used as a switching device in the inverter circuit. The PWM signal from the driver IC is fed to the gate of the switch. The output from the inverter circuit is given to the motor.

B. *LPF*

The motor after sensing the three-phase terminal voltages; each of the three-phase terminal voltages is fed into an LPF to suppress the high switching frequency ripple or noise. The output of the low pass filter is given to the ZCD block.

C. *ZCD*

The purpose of zero crossing detector in our project is to transmit the AC signal to digital signal. It will detect the pulse when the current reaches the zero crossing point of the wave. The output of ZCD is fed to the controller kit as the input.

D. *DSPIC Controller*

The proposed control for BLDC motor control using DSPIC microcontrollers with device name DSPIC30F4011. The square pulses from the ZCD block are sent as an input to the controller. The Controller reads the captures and the corresponding six pulses for the inverter are generated through coding.

E. *Optocoupler*

The function of Optocoupler is to isolate the control circuit from the power circuit. The PWM signal from the controller is not directly fed to the power circuit. In order to protect the PWM signal, it is essential to provide isolation circuit between power circuit and control circuit or else the high power components may damage the low power PWM circuit components.

F. *Driver Circuit*

The MOSFET drive circuit is designed to connect the gate directly to a voltage bus with no intervening resistance other than the impedance of the drive circuit switch. The Gate driver acts as a high-power buffer stage between the PWM output of the control device and the gates of the primary power switching MOSFET.

IV. SIMULATION RESULTS

The proposed Sensorless method is simulated in MATLAB software. The simulation was carried out for the maximum

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variation of set speed range from 0 to 3000 RPM. The simulation results are shown in the following waveforms.

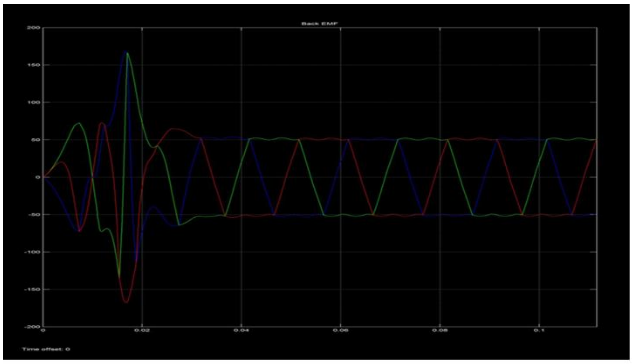

Fig 3. Back emf waveform

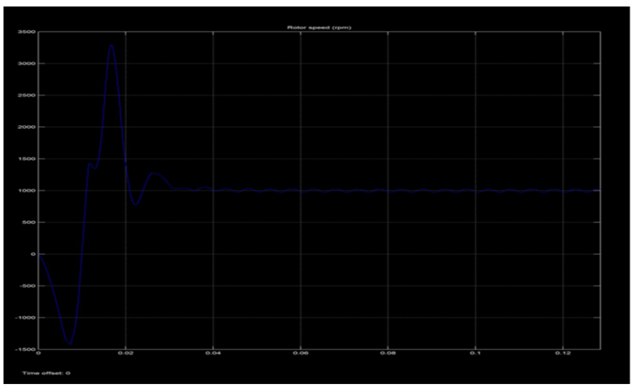

Fig 4. Speed waveform

From the above speed waveform, we can able to observe that the Sensorless control of BLDC motor is achieving the constant speed.

V. HARDWARE

The hardware for this Sensorless control method consists of an inverter circuit, control circuit and the multi output power supply. The complete hardware set up for the motor control is shown in fig

Fig 5. Hardware

VI. CONCLUSION

This paper has proposed a new Sensorless control method for BLDCMs based on the zero crossing detection of back emf. The proposed technique has been programmed into the DSPIC30f4011 microcontroller [4] and it generates the firing pulses required to drive the MOSFETs of three phase fully controlled bridge converter. The output from the converter is fed to the three phase stator winding of 24V, 60 W, 3000 RPM BLDC motor and the motor are found to run at constant speed. The program is found to be efficient and the results with the designed hardware are promising. The motor is found to start smoothly and run Sensorless even with load and load transients.

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